

YTH TRANSLATION
JP Application 2001-242808

Translation of JP Application 2001-242808

Application Date: August 9, 2001
Application No.: P 2001-242808

TITLE: ORGANIC SEMICONDUCTOR SOLUTION, ORGANIC SEMICONDUCTOR THIN FILM,
AND ORGANIC SEMICONDUCTOR ELEMENT

INVENTOR: Takashi Minakata

APPLICANTS: Asahi Kasei Kabushiki Kaisha

1. TITLE OF INVENTION

Organic semiconductor solution, organic semiconductor thin film, and organic semiconductor element

2. ABSTRACTS

[Goals]

To offer the organic semiconductor solution which enables the easy formation of the organic semiconductor thin film without defects at a low cost. Further, the present invention offers the organic semiconductor thin film without defects and the organic semiconductor element with the superior electronic characteristics.

[Solution methods]

A transistor was prepared by forming an organic semiconductor thin film 1 by laminating a gate electrode 3, insulation layer 3, and source and drain electrodes 4 on a glass substrate 5 in this order, and further by coating o- dichloro benzene solution of pentacene (0.05 mass%) thereon and drying.

[Selected Figure]

Figure 3

3. PATENT CLAIMS

[Claim 1]

An organic semiconductor solution comprising polyacene compounds and the solvent, at least a part of which is constituted with polyacene compound dissolving solvent which can dissolve the said polyacene compounds, wherein the said polyacene compound dissolving solvent is characteristically at least one type from: aromatic halogenized hydrocarbons, aliphatic halogenized hydrocarbons, aromatic hydrocarbons, lactone compounds, and carbonate compounds.

[Claim 2]

The organic semiconductor solution described in Claim 1, wherein the said aromatic halogenized hydrocarbon is characteristically the di- halogenized aromatic hydrocarbon.

[Claim 3]

The organic semiconductor solution described in Claim 1 or 2, wherein the content of the said polyacene compound is 0.01 to 8 mass% of the total and the content of the said polyacene compound dissolving solvent is characteristically 10 to 99.99 mass% of the total.

[Claim 4]

The organic semiconductor solution described in one of Claims 1 to 3, wherein the electron donor molecules or electron acceptor molecules which can form the charge transfer complex with the said polyacene compound are characteristically comprised at the amount of at most 10 mass % of the total.

[Claim 5]

The organic semiconductor thin film which is made by vaporizing the said solvent from the organic semiconductor solution described in one of Claims 1 to 4.

[Claim 6]

The organic semiconductor thin film described in Claim 4 which is made by vaporizing the said solvent from the organic semiconductor solution, wherein at least a part of the said electron donor molecules or electron acceptor molecules are characteristically removed.

[Claim 7]

A manufacturing method of the organic semiconductor thin film which characteristically controls the crystal growth of the said polyacene compound by applying at least one of: the temperature gradient, electric field, and magnetic field at the vaporization of the said solvent from the organic semiconductor solution described in one of Claims 1 to 4.

[Claim 8]

An organic semiconductor element, at least a part of which is characteristically constituted with the organic semiconductor thin film described in Claim 5 or 6, or the organic semiconductor thin film manufactured by the manufacturing method of the organic semiconductor thin film described in Claim 7.

4. DETAILED INTERPRETATION OF INVENTION

[Technical Fields]

The present invention relates to the organic semiconductor thin film which can be suitably employed for electronics, photonics, and bio- electronics. Further, this relates to the organic semiconductor solution which is the raw material of the said organic semiconductor thin film. Further, this relates to the organic semiconductor element utilizing the said organic semiconductor thin film.

[Background Techniques]

In the device utilizing the organic semiconductor, the film formation condition is milder compared to the conventional inorganic semiconductor devices, thus the

semiconductor thin film may be formed on various substrates and may be formed at room temperature. Therefore, its potential for the low cost and flexibility by forming the thin film on a polymer film is anticipated.

As the organic semiconductor material, the polyacene compounds such as anthracene, tetracene, and pentacene, as well as poly- phenylene vinylene, polypyrrole, poly- thiophene, and oligo- thiophene, have been studied. Particularly the polyacene compounds possess the high crystallinity due to the strong molecular coagulation force. Therefore, a high carrier mobility and the exhibition of the superior semiconductor device characteristics have been reported.

As the utilization forms of the polyacene compounds to the device, the vapor deposition film or single crystal are named and the applications to the transistor, solar cell, and laser have been evaluated (Schone, et al., Science, 289, p 559 (2000) and Science, 287, p 1022 (2000); Dimitrakopoulos, et al., J. Appl. Phys., 80, p 2501 (1996); Schone, et al., Nature, 403 p 408 (2000); and Croke, et al., IEEE Trans. Electro. Device, 46, p 1258 (1999)).

[Problems Solved by the Invention]

However, these vapor deposition film and single crystal are prepared within a vacuum container, thus the device is expensive and complex. Further, in the case of the single crystal, the applicable element size is limited. On the other hand, the method to prepare a thin film of pentacene, a type of the polyacene compound, has been reported by coating the pentacene precursor solution on a substrate and by heat treating this (Brown et al, J. Appl. Phys., 79, p 2136 (1996)). Since the polyacene compound is hardly soluble, the thin film is formed from the solution of the precursor having the high solubility and the precursor is converted to the polyacene compound by heat.

However, such the method utilizing the precursor has problems: the necessity of a high temperature treatment at about 150 °C to convert the said precursor to the polyacene compound; the remains of the unreacted sections as the defects since the complete conversion reaction to the polyacene compound is difficult; and the defects formed by the deformation by high temperature.

Therefore, the present invention aims to solve the problems of the said conventional techniques and to offer the organic semiconductor solution which enables the easy formation of the organic semiconductor thin film with a high crystallinity without defects at a low cost. Further, the present invention aims to offer the organic semiconductor thin film without defects and the organic semiconductor element with the superior electronic characteristics.

[Methods to solve the Problems]

in order to solve the said problems, the present invention has the following constitution. In other words, the organic semiconductor solution of the present invention comprises polyacene compounds and the solvent, at least a part of which is

constituted with polyacene compound dissolving solvent which can dissolve the said polyacene compounds, wherein the said polyacene compound dissolving solvent is characteristically at least one type from: aromatic halogenized hydrocarbons, aliphatic halogenized hydrocarbons, aromatic hydrocarbons, lactone compounds, and carbonate compounds.

Such the organic semiconductor solution can manufacture the organic semiconductor thin film by the method to coat the organic semiconductor solution on the base such as the substrate and to vaporize the said solvent. Therefore, the organic semiconductor thin film can be manufactured more easily and at a low cost. Further, this organic semiconductor solvent is the solution in which the polyacene compound is dissolved. Therefore, there are no said problems associated with the method utilizing the precursor, in other words, the necessity of a high temperature treatment during the manufacturing; and the easy occurrence of defects originated from the unreacted sections and the deformed section in the organic semiconductor thin film.

Examples of polyacene compound are; anthracene, tetracene (naphthacene), pentacene, hexacene; further the derivatives of these polyacene compounds, in other words, the derivatives introducing the substitution groups such as alkyl group, alkoxy group, halogen group, ketone group, ester group, ether group, amino group, hydroxyl group, benzyl group, benzoyl group, phenyl group, and naphthyl group, into the said polyacene compounds; and the quinone derivatives of the said polyacene compounds. Here, these polyacene compounds and the polyacene compound derivatives may be used solely or by mixing at least two types.

The content of the said polyacene compounds within the total of the organic semiconductor solution is desirably from 0.01 to 8 mass%. Less than 0.01 mass% may cause the problems: the thickness of the formed organic semiconductor thin film may be too thin and the region which may not be coated with the organic semiconductor solution may occur on the said base. On the other hand, more than 8 mass% may cause the inconveniences such as: making the organic semiconductor solution unstable, i.e., the polyacene compound tends to be precipitated from the organic semiconductor solution; or making the surface of the formed organic semiconductor thin film coarse.

In order to make the occurrence of such the inconveniences harder, the content of the polyacene compound is more desirably from 0.02 to 5 mass% and most desirably from 0.05 to 3 mass%. Further as the polyacene compound dissolving solvent of the present invention, aromatic halogenized hydrocarbons, aliphatic halogenized hydrocarbons, aromatic hydrocarbons, lactone compounds, and carbonate compounds are desirable.

Examples of aromatic halogenized hydrocarbons are: chloro benzene, bromo benzene, iodo benzene, o- dichloro benzene, m- dichloro benzene, o- dibromo benzene, m- dibromo benzene, o- diiodo benzene, m- diiodo benzene, chloro toluene, bromo toluene, iodo toluene, dichloro toluene, dibromo toluene, difluoro toluene, chloro

xylene, bromo xylene, iodo xylene, chloro ethyl benzene, bromo ethyl benzene, iodo ethyl benzene, dichloro ethyl benzene, dibromo ethyl benzene, chloro cyclo-pentadiene, and chloro cyclo- pentadiene **[Note from the Translator-** The last entry is duplicate.].

Further, examples of aliphatic halogenized hydrocarbons are: chloroform, bromoform, dichloro methane, dichloro ethane, trichloro ethane, difluoro ethane, fluoro chloro ethane, chloro propane, dichloro propane, chloro pentane, and chloro hexane. And further, examples of aromatic hydrocarbons are: toluene, xylene, mesitylene and methyl naphthalene.

Further, examples of lactone compounds are: γ - butylo- lactone and propio- lactone. Further, examples of carbonate compounds are: dimethyl carbonate, diethyl carbonate, methyl ethyl carbonate, propylene carbonate, and butylene carbonate.

Among the said polyacene compound dissolving solvents, the aromatic halogenized hydrocarbons and aliphatic halogenized hydrocarbons are more desirable due to a high solubility of the polyacene compounds. Among the aromatic halogenized hydrocarbons, di- halogenized aromatic hydrocarbons are particularly desirable by having a high solubility for the polyacene compounds having a large condensed ring number such as pentacene and hexacene.

These polyacene compound dissolving solvents may be used as the solvent for the organic semiconductor solution solely or by mixing at least two types. At this time, the content of the polyacene compound dissolving solvent within the whole organic semiconductor solution is desirably at most 99.99 mass%. More than 99.99 mass% excessively reduces the content of the polyacene compound, which may cause the said inconveniences: the thickness of the formed organic semiconductor thin film may be too thin and the region which may not be coated with the organic semiconductor solution may occur on the said base.

Further, by considering the control of the solvent vaporization rate during the manufacturing of the organic semiconductor thin film and the influence (dissolution, swelling, and so on) to the base to which the organic semiconductor solution is coated, the solvents besides the polyacene compound dissolving solvent may be mixed to utilize it as the solvent of the organic semiconductor solution. At this time, the content of the polyacene compound dissolving solvent within the whole organic semiconductor solution is desirably at least 10 mass%. Less than 10 mass% reduces the solubility of the polyacene compound and makes it difficult to obtain the organic semiconductor solution in which the sufficient amount of the polyacene compound is dissolved.

In such the organic semiconductor solution, the electron donor molecules or electron acceptor molecules which can form the charge transfer complex with the polyacene compound may be comprised. Then, the solubility of the polyacene compound is increased and the high concentration solution can be prepared. Examples of the donor molecules are: TTF compounds such as tetra- thia fulvalene,

tetra methyl tetra- thia fulvalene, tetra- seleno thia fulvalene; phenylene diamine type compounds such as tetra- phenyl diamino diphenyl, tetra- phenylene diamine, and diphenyl phenylene diamine; aromatic amine compounds such as polyvinyl carbazole; and fullerene (carbon cluster represented by C_{60}), alkali metal complex, and alkali earth metal complex.

Examples of the acceptor molecules are: halogens such as iodine, bromine, chlorine, iodine chloride, and iodine bromide; oxidized sulfur compounds such as sulfate anhydride, sulfur dioxide, sulfuric acid, and sulfates; oxidized nitrogen compounds such as nitric acid, nitrates, and nitrogen dioxides; halogenized compounds such as perchloric acid and hypochlorous acid; acids and salts such as tetra- fluoro boric acid, tetra- fluoro borates, phosphoric acid, and phosphates; organics compounds such as tetra- cyano quino- dimethane, tetra- chloro tetra- cyano quino- dimethane, tetra- fluoro tetra- quino- dimethane, tetra- cyano ethylene, dichloro dicyano quinone, and tetra- chloro quinone; and carbonic acid gas and oxygen.

These doner molecules and acceptor molecules may be used solely or by mixing at least two types. However, when the doner molecules and acceptor molecules are used by being mixed, the doner molecule and acceptor molecule form a complex, which may undesirably impair the solubility of the polyacene compounds. The content of the doner molecules and acceptor molecules (which is called as the dopant) is desirably at most 10 mass%. More than 10 mass% tends to form the carrier defects by the dopant due to the excessively large residual amount of the dopant in the organic semiconductor thin film.

The polyacene compounds form the p- type semiconductor at the undoped condition in the air and the holes play a role of the carrier. However, the element using the undoped thin film tends to show the high resistivity due to the small number of the carriers, thus the operation conditions and element structures are limited. As a result, the adjustment of the carrier types and carrier density by introducing the dopant is desirable for the element performance and the structure. In the polyacene compound thin film (organic semiconductor thin film) comprising the acceptor molecules, the hole carriers are further increased by the acceptor molecules, which is desirable by enabling the manufacturing of the element with a low resistivity, high gain, and a high current.

On the other hand, in the polyacene compound thin film comprising the doner compound, the hole carriers are reduced with the increase in the doner molecule content and the electron carriers are increased. At this process, the control of the content of the donor molecule can vary the semiconductor to the p type, i type, and to the n type, thus it may be utilized as the i type semiconductor or the n type semiconductor, or the various semiconductor element structures such as the p- i- n structure, p- n structure, n- p- n structure, and the p- n- p structure are desirably formed.

Below, the organic semiconductor thin film of the present invention is interpreted. The organic semiconductor thin film of the present invention can be obtained by coating the said organic semiconductor solution on a base such as the

substrate and by vaporizing the said solvent by such the measures as heating. The concrete methods to coat the base with the organic semiconductor solution are, for example, the known methods such as the spin coat, dip coat, screen printing, inkjet printing, and the blade coating methods.

Such the operation can be carried out under the ordinary atmosphere, or under the inert gas atmosphere such as nitrogen or argon. Here, some polyacene compound solution may be easily oxidized, therefore, the preparation, storage, and the manufacturing of the organic semiconductor thin film are desirably carried out under the inert gas atmosphere. Further when the solvent is vaporized, the crystal growth can be controlled by the control of the solvent vaporization rate of the gas- liquid interface through the temperature near the base and the solvent vapor pressure within the atmosphere. Further, it is possible to form the organic semiconductor thin film on the base surface at the super- saturated condition by placing the base in contact with the organic semiconductor solution. Further, the crystal growth can be controlled by applying at least one of: the temperature gradient, electric field, and the magnetic field to the interface of the organic semiconductor solution and the base, as desired. By these methods, the manufacturing of the organic semiconductor thin film with a high crystallinity is possible and the obtained organic semiconductor thin film has the superior semiconductor characteristics by having a high crystallinity.

Further, from the view points of the organic semiconductor thin film stability and the semiconductor characteristics, the amount of the solvent remained in the organic semiconductor thin film is desirably low. Therefore, it is usually desirable to remove the solvent remaining within the organic semiconductor thin film almost completely by applying the re- heating after forming the organic semiconductor thin film. Further, in the organic semiconductor thin film of the present invention, the long axis of the polyacene compound molecule tends to align the perpendicular direction of the base surface during the crystal formation. This is attributed to the strong molecular coagulation force of the polyacene compound molecules, which tends to form molecular columns stacked between molecular surfaces. Therefore, the X- ray diffraction pattern of the organic semiconductor film tends to show the strong intensity of the (00n) plane of the crystal. The organic semiconductor element constituted with such the organic semiconductor thin film has such the characteristic that the carrier tends to flow along the said molecular column.

Further the crystallinity of the usual inorganic semiconductor thin film is influenced by the crystallinity and the planer direction of the base material. However, the organic semiconductor thin film of the present invention forms the high crystallinity thin film regardless to the crystallinity and the planer direction of the base material. Therefore, the various materials may be used as the base material regardless to the crystallinity and non- crystallinity. Examples are: ceramics such as glass, quartz, aluminum oxide, sapphire, silicon nitride, and silicon carbide; semiconductors such as silicon, germanium, gallium arsenic, gallium phosphorous, and gallium nitrogen; polyesters such as polyethylene terephthalate and polyethylene naphthalate; the resins such as polyethylene, polypropylene, polyvinyl alcohol, ethylene vinyl alcohol co-

polymer, cyclic polyolefin, polyimide, polyamide, and polystyrene; and paper and unwoven cloth.

The shape of the base is not limited to any specifics, and the sheet- like base (substrate) is usually employed. Further, in the organic semiconductor thin film formed by the organic semiconductor solution having a dopant, the organic semiconductor thin film may be manufactured by removing a part or all of the dopant at or after the formation of the organic semiconductor thin film.

For example, after the organic semiconductor thin film is formed from the organic semiconductor solution comprising iodine as the acceptor molecule, the iodine molecules may be removed from the organic semiconductor thin film by maintaining at the temperature of 150 °C under the inert gas flow. As described above, the electronic characteristics of the organic semiconductor thin film can be controlled by controlling the carrier concentration through the adjustment of the dopant content within the organic semiconductor thin film. Further, the organic semiconductor thin film may be introduced with the dopant (doped) later as necessary.

By employing such the organic semiconductor thin film, the semiconductor element useful in the electronics, photonics, and bio- electronics may be manufactured. Examples of such the semiconductor element are: diode, transistor, thin film transistor, memory, photodiode, luminescent diode, luminescent transistor, gas sensor, bio-sensor, blood sensor, immuno- sensor, artificial retina, and taste sensor.

Examples of the manufacturing method of the said semiconductor elements are: the method to form the organic semiconductor thin film by coating the said organic semiconductor solution with a pattern on the desired region of the preliminarily pattern formed electrode, semiconductor, and insulation layers; and the method to carry out the patterning of the said thin film and the formation of the electrode and insulation film after the formation of the organic semiconductor thin film.

At this time, the applicable patterning method is the etching method with polyacene compound dissolving solvents or plasma after forming the resist pattern and mask layer. Further it is possible to form the semiconductor element by lamination and to form the protective layer and light shielding layer after the formation of the semiconductor element. Here, when the solutions are employed to form various electrodes, insulation layers, and protective layers during the formation of such the semiconductor element, it is desirable for the said polyacene compound dissolving solvents not to directly be in contact with the organic semiconductor thin film. And it is desirable to install the barrier layer to protect the organic semiconductor thin film from the said solvents when the said polyacene compound dissolving solvents are used.

[Best Execution Forms of Invention]

The execution forms of the organic semiconductor solution, organic semiconductor thin film, and the organic semiconductor element of the present invention are interpreted in details by referencing the figures. Here, the present

execution forms present the examples of the present invention and the present invention is not limited by the present execution examples.

[Example 1]

Naphthacene was dissolved in o- dichloro benzene to prepare the solution having the 5 mass% naphthacene concentration. The said solution was cast on a glass substrate and dried to form a thin film with a film thickness of 350 nm. The measurement result of the X ray diffraction pattern (Cu K α line) of the said thin film showed the 00n plane (n = 1, 2, 3) peaks with the c axis lattice constant of 1.3 nm (see Figure 1), which revealed it is the crystalline thin film.

[Example 2]

Pentacene was dissolved in o- dichloro benzene to prepare the solution having the 0.05 mass% pentacene concentration. The said solution was coated on a glass substrate several times and dried to form a thin film with a film thickness of 90 nm. As similarly in Example 1, the measurement result of the X ray diffraction pattern of the said pentacene thin film showed the 00n plane (n = 1, 2, 3, 4, 5) peaks with the c axis lattice constant of 1.5 nm (see Figure 2), which revealed it is the crystalline thin film.

[Example 3]

For the hexacene, the method in the literature (Minakata, et al., Polymer Advanced Tech, 5, p.602 (1995)) was employed. In other words, naphthalene di-aldehyde and anthracene di- hydroquinone were reacted within ethanol under the existence of alkali to synthesize di- hydroxy hexacene quinone. This di- hydroxy hexacene quinone was reduced with lithium aluminum hydride to synthesize di- hydro hexacene, and further hexacene was obtained by eliminating hydrogen with copper (I) oxide under the existence of palladium catalyst. The crystalline powder of hexane was obtained by the sublimation purification.

Hexacene synthesized as above was dissolved in o- dichloro benzene to prepare the solution having the 0.05 mass% hexacene concentration. The said solution was coated on a glass substrate several times under the inert gas atmosphere and dried to form a thin film. As similarly in Example 1, the measurement result of the X ray diffraction pattern of the said hexacene thin film showed the 00n plane (n = 2, 3) peaks with the lattice constant of 1.8 nm, which revealed it forms the crystalline thin film.

[Examples 4 to 9 and Comparison Examples 1 to 4]

By the similar method in Example 1, the solutions in which polyacene compound was dissolved in various solvents were prepared, and the thin films were prepared by the said solutions. Then, the X ray diffraction patterns were measured from the said thin films. Table 1 summarizes the types of the polyacene compounds and solvents, solution concentrations, thin film thickness, and the thin film crystallinity [Note from the Translator- There is no Table 1.].

As apparent from Table 1, Examples 4 to 9 resulted in the thin films having the crystallinity with the c axis alignment as similarly as Examples 1 to 3. On the other

hand, Comparison Examples 1 to 4 using the solvents to which the solubility of the polyacene compound is extremely low, did not result in the thin film since the polyacene compound was hardly dissolved. Here in Table 1, "< 0.01" indicates the concentration of the polyacene compound to be less than 0.01 mass%.

[Example 5]

The solution was prepared by dissolving pentacene into o- dichloro benzene dissolving 3 mass% of iodine (pentacene: 0.08 mass%, iodine: 3 mass%, and o- dichloro benzene: 96.92 mass%). The said solution was coated on a glass substrate and dried to form a thin film with a film thickness of 150 nm as similarly in Example 2. As similarly as above, the measurement result of the X ray diffraction pattern of the said pentacene thin film showed the 00n plane (n = 1 ~ 8) peaks with the c axis lattice constant of 1.9 nm, which revealed it forms the crystalline thin film.

This thin film was slightly reddish and the containment of iodine as the dopant was confirmed by the absorption near 320 nm and 500 nm at the visible absorption spectrum measurement. Such the pentacene thin film was formed on the glass substrate on which the gold electrodes are formed by vapor deposition, as similarly as above. The electric conductivity of the pentacene thin film measured by the resistivity between the electrodes was 0.1 S/cm (1 /ohm · cm).

[Example 6]

The pentacene thin film comprising iodine prepared in Example 5 was heated at 150 °C for 10 minutes within the inert gas flow. The measurement result of the X ray diffraction pattern of the pentacene thin film after heating showed the 00n plane (n = 2 ~ 6) peaks with the c axis lattice constant of 1.5 nm, which revealed the formation of the crystal same as the pentacene thin film prepared in Example 2. Here, the pentacene thin film after the heating process showed the blue color and the said absorption's originated from the iodine disappeared in the visible absorption spectrum measurement. Therefore, the removal of iodine from the thin film was observed.

Th pentacene thin film formed on the glass substrate on which the gold electrodes were formed by vapor deposition in Example 5 was applied with the heat treatment the same as above to remove the iodine from the thin film. Then, the electric conductivity was measured to be 10^{-4} S/cm.

[Example 7]

Metallic lithium was dispersed in the THF- toluene solution of butyl lithium (butyl lithium: 3 mass%, and THF/ toluene = 10/ 90) under the inert gas atmosphere. And the solution was prepared by adding and dissolving pentacene powder. By filtering the obtained solution, the undissolved pentacene powder and metallic lithium were filtered off. This filtered product was washed with methanol to dissolve only metallic lithium and remained pentacene powder was dried and quantitatively measured. As a result, the pentacene concentration of the prepared solution was revealed to be 0.06 mass%.

The said pentacene solution was coated on the glass substrate within the inert gas flow and dried to prepare the thin film with a thickness of 20.6 nm. The electric conductivity of this thin film measured by the method used in Example 5 was 0.002 S/cm. This result indicates that the metallic lithium or butyl lithium acted as dopant and reduced the resistivity.

[Example 8]

The electric field effect transistor, one execution form of the organic semiconductor element of the present invention is interpreted by referencing Figure 3. The gate electrodes 2 obtained by patterning the electron beam vapor deposited gold thin film, the insulation layer 3 obtained by the reactive ion etching (RIE) of the sputtered SiO₂, and the source and drain electrodes 4 and 4 obtained by patterning the electron beam vapor deposited gold thin film were laminated on the glass substrate 5 in this order. Then, the transistor was prepared by coating and drying the pentacene solution in Example 2 thereon to form the organic semiconductor thin film 1.

For this transistor, the voltage and current between the source and drain electrodes were measured at the gate voltages of 10 V and -30 V (see the current - voltage curve in Figure 4). The result showed that the mobility was 0.2 cm²/V · sec at the on/ off current ratio of 10⁵, indicating it was working as the electric field effect transistor.

[Example 9]

The transistor was prepared by the same procedure as Example 8 except that the polyethylene terephthalate was used as the substrate and the solution of Example 5 was used as the organic semiconductor solution. The said transistor was heat treated at 120 °C for 10 minutes.

For the transistor obtained above, the voltage and current between the source and drain electrodes were measured by the same procedure as Example 8. The result showed that the mobility was 0.2 cm²/V · sec at the on/ off current ratio of 10⁵.

[Effect of Invention]

As described above, the organic semiconductor solution of the present invention enables to form the polyacene compound thin film without defects at a low cost. Further, the organic semiconductor thin film of the present invention has very few defects and a high crystallinity, thus the semiconductor characteristics are superior.

Further, the organic semiconductor element of the present invention has the superior electronic characteristics.

[Simple Interpretation of Figures]

Figure 1 – An X-ray diffraction pattern of naphthacene thin film.

Figure 2 – An X-ray diffraction pattern of pentacene thin film.

Figure 3 – A cross- section diagram presenting the constitution of the electric field effect transistor, one execution from of the organic semiconductor element of the present invention.

Figure 4 – A current- voltage curve for the electric field effect transistor.

[Codes]

1 – organic semiconductor thin film

5 – glass substrate

Figure 1

Diffraction Intensity

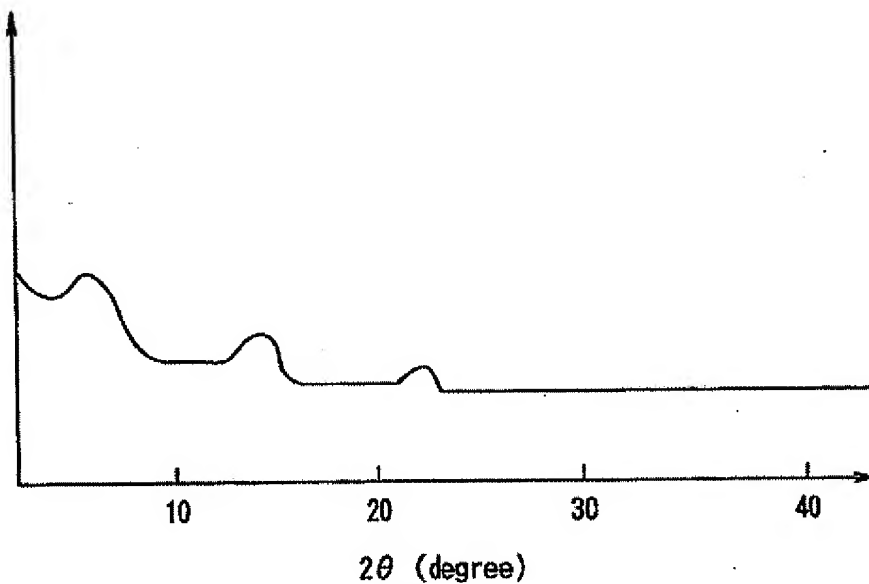


Figure 2
Diffraction Intensity

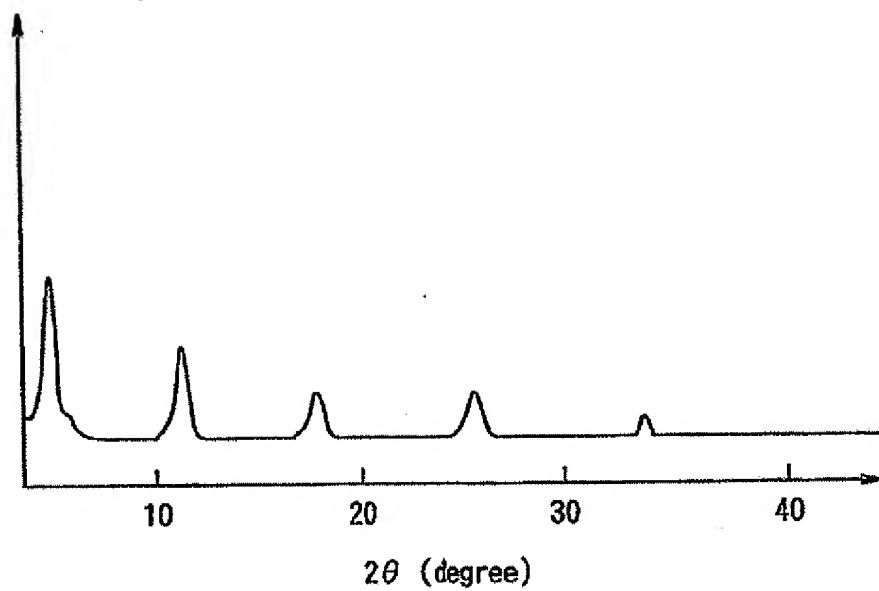


Figure 3

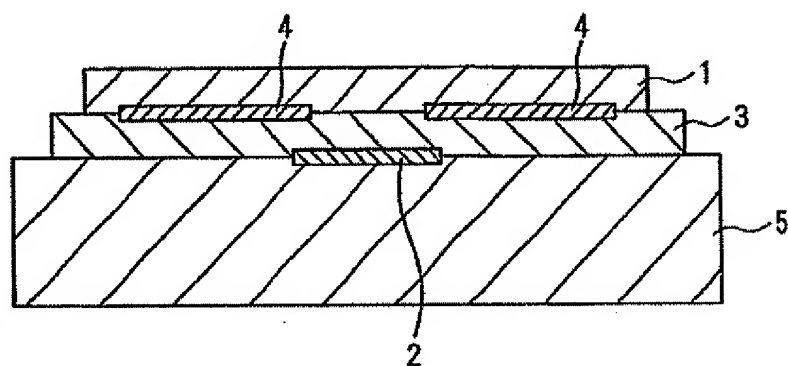


Figure 4

